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AUTOMATIC TRANSMISSION DEVELOPMENT

Ronald J. Shuman

"I think we impute to engineers, I mean those who design things, a degree of foresight they can only wish they had. It is as though the final form of a device were implicit in the engineer's description of what is needed. That, of course, is rubbish!"

(Heard in a cafeteria)

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AUTOMATIC TRANSMISSION DEVELOPMENT

I. INTRODUCTION

By the early 1920's, when engineers at General Motors began working on the problem, there had already been many attempts to develop an automatic transmission for passenger cars; most of them were crude and none were completely successful. Not until 1939 did the G.M. engineers come up with a satisfactory solution; the device was called Hydra-Matic, it was the first fully automatic transmission for passenger cars to reach production, and in that year about 25,000 Oldsmobiles equipped with them were sold. Nearly twenty-five years later, in 1963, Earl A. Thompson received the Sperry Award, given in recognition of "a distinguished engineering contribution which, through application, proved in actual service, has advanced the art of transportation whether by land, sca, or air."

Thompson had been in charge of a group of General Motors engineers which developed the Hydra-Matic. By 1963 over 13 million of these transmissions had been produced, along with many millions more designed by other firms which operated upon the principle inaugurated with the Hydra-Matic.[1] It happens that another G.M. engineer was engaged in automatic transmission research during the twenties; his name was J. O. Almen. Almen's work was carried out independently of Thompson's (although, as we will see, the careers of the two men were to cross in a curious way) and its outcome was altogether different.

1. "The capability of changing drive ratios without relaxation of torque by use of hydraulic servo-mechanisms actuating internal systems of clutch bands and plates." Sperry Award Brochure, 1963, page 16.

Many of us imagine that engineering work consists pretty much of searching for and perfecting "correct" solutions to technical problems. The obvious fact, often overlooked (I almost said "suppressed"), is that these activities are carried on by human beings. Design is a form of self-expression, personalities are involved, sometimes personalities in conflict. What follows is an account of one instance, the development of the automatic transmission, in which a particular set of circumstances influenced the direction of engineering work. The story will be easier to follow if we begin with some background on the subject of automotive transmissions.

II. BACKGROUND

The gasoline engine is inherently lcss suitable than the steam engine or the electric motor to propel a vehicle because it has no starting torque and must be set in motion before it can deliver any power.[2] This characteristic necessitates some type of unloading and engaging device to permit gradual application of load to the engine after it has been started.

The torque produced by the engine is low at low crankshaft speeds, increases to a maximum at some fairly high speeds, then decreases as the throttle is further advanced. Maximum horsepower is attained only when the crankshaft is turning at its rated speed. The specific fuel comsumption of an automobile engine is best when the load on the engine is high and the throttle

2. This discussion taken in part, from Encyclopedia Britannica, Vol. 2, p. 37, ff.

is nearly wide open. At moderate speeds on level pavement the power required to propel an automobile is only a portion of the power an engine is capable of developing in its upper range of speeds. Thus, under such conditions, the engine may operate at an uneconomically light load unless some means are provided to reduce its speed and power output.

A speed-changing device, or gearbox, permits the engine to operate at a higher speed when its full power is needed. Under some conditions, as in starting a stationary vehicle or ascending a steep grade, the torque of the engine is insufficient and amplification is desirable. Most devices employed to change the ratio of the speed of the engine to the speed of the driving wheels multiply the engine torque by the same factor that the engine speed is increased. Such devices are most commonly called transmissions.

Traditionally, of course, gear changing was controlled by the driver; each change of gears had to be accomplished by coordinating clutch, throttle, and shift lever. Why then, if passenger cars performed adequately with manual transmissions, and if most drivers could learn, with a bit of practice, to handle the task of gear changing, did G.M. set out to develop an automatic transmission? In a paper called "Automatic Transmissions in America"[3] Charles A. Chayne (an automotive engineer who was, until his retirement, a G.M. Vice President) proposes an answer to this question. Technically speaking, he says, the high-powered passenger car of today has the least need for an automatic transmission as far as its performance is concerned. The problem also presents so many cost, weight, and size limitations, together with conflicting requirements for performance, pleasability, and efficiency, as to make it an extremely difficult job. However, the multi-billion dollar passenger car industry offers the greatest promise of commercial rewards for any outstanding new features or developments. The greater part of all engineering effort, therefore, has been expended in developing drives for passenger cars.

So, the motive was simple: profit. However strong the motivation (whether corporate or individual; they may differ, of course) automatic transmission designers had to contend with commercial as well as technical problems; here is the way Chayne summarizes them: "The task is not simple and the requirements are many. The passenger car transmission must satisfy the average owner-driver. What pleases him most is his own idea of the best combination of reliability, noiselessness, smooth performance, and flashy acceleration when needed. He wants fully automatic normal driving with easily operating, smoothly acting, forward and reverse controls; reasonable safety controls such as engine braking and neutral starting switch; efficiency as it affects gas economy, and above all, a reasonable initial cost. Obviously, when so many considerations have to be weighed for the best compromise in determining the design, there are bound to be many differences of opinion as to which is the best design in passenger car automatic transmissions."

This passage raises an intriguing question: in a large corporation, General Motors for example, who makes such decisions? Who decides which criteria are most important; who determines whether a particular

3. Presented to the British Institution of Mechanical Engineers, November 4, 1952.

requirement has been met; and, when there are "differences of opinion" (or conflicts) among engineers as to which design is best, who has the final say? The answer to this last question is crucial to our story. There is another item of interest in the Chayne paper; it has to do with one of the earliest American attempts to create an automatic transmission, the Carter Car Friction Drive. This, Chayne says, was one of the many early approaches to friction drive. "But it too fell by the wayside. Like all friction drives it encountered a difficult metallurgical problem in the life of the driving surfaces; and if designed to reduce driving-surface stresses, the unit becomes too bulky and inefficient for the modern car. The friction drive was extensively reinvestigated by General Motors just prior to the development of the Hydra-Matic. The basic concept involved was to provide an infinitely variable transmission by varying the angle of a roller assembly between two torus races, a driving and driven race. Rotating the roller assemblies on their pivot axis clockwise between their races provides an infinite number of underdrive speeds. Likewise, rotating them counter-clockwise provides an infinite number of overdrive ratios. The development program on this transmission started in 1928 and continued through the early 1930's. Over 400,000 miles of testing were given to more than thirty of these units; and though the program was dropped because of metallurgical reasons, it did establish the basic requirements that any automatic transmission should be designed to meet."

The infinitely variable transmission Chayne refers to was developed by J. O. Almen and a group of engineers working under him at General Motors during the late twenties and early thirties; a diagram of it is shown in Exhibit 1; during this same period the Thompson group began investigating the concepts which would ultimately lead to the Hydra-Matic.

Chayne's description of what happened to the I.V. transmission may, however, be oversimplified, in particular his phrase "just prior to the development of the Hydra-Matic." The two programs were carried on in parallel, they were competitors. At a certain point the order came down from highest management that work on the I.V. transmission should cease, while the work of Thompson's group was to continue. The Almen transmission, whatever its conceptual problems, was then a real device; but the Hydra-Matic, in anything resembling its final form, was not to appear for several years.

The introduction of the Hydra-Matic in 1939 climaxed a complex series of events. How the story is told, which details are stressed and which omitted, depends pretty heavily upon whose point of view the teller adopts. With this in mind let us take a closer look at the development of the automatic transmission, first from Thompson's point of view, then from Almen's.

III. Earl Thompson and the Hydra-Matic Transmission: 1932-1939

Earl Thompson was born in Elgin, Oregon, on July 1, 1891.[4] He was educated at Oregon State University where he majored in mechanical and electrical engineering. In 1913 Thompson undertook his first

4. Material in this section paraphrased from the Sperry Award Brochure, 1963. See SAE Journal, March 1964, pages 102 and 103.

important engineering job, the design of a pump for a municipal water project in Opal Springs, Oregon. This and a company he formed to wire buildings for electricity occupied Thompson during the early years of his career; but he had an interest in automobile transmissions which dated from his days as a student. He began to think about ways of making gear shifting easier, and it occured to him that there should be a way of mechanically synchronizing the speeds of the rotating drive and driven gears at the time of shifting so that the operator need not pause between disengagement of one gear and engagement of the next. He conceived the idea of interposing individual cone clutches between the toothed clutches to achieve such synchronization. By 1922 Thompson had constructed a model transmission which embodied this idea, and in April of that year, armed with drawings and data for a prototype synchromesh transmission, he set out for Detroit to sell it to the automobile industry. But the automoile manufacturers were not impressed; their customers, he was told, were satisfied with transmission just as they were. Thompson persisted. After several trips between Oregon and Detroit, and months spent improving the design, he was finally able to arrange a meeting with Lawrence Fisher, managing director of Cadillac Motor Car Division and Ernest Seaholm, Cadillac's chief engineer. They were interested in the idea, and Thompson was retained as a consultant while the transmission was perfected. In 1928, after three years of redesign, the synchromesh transmission reached production and Thompson, at Seaholm's invitation, joined Cadillac as assistant chief engineer.

The synchromesh represented a great improvement in automotive transmission design. Shifting now was easier, but one still had to shift. Thompson knew that a good deal of experimental work had been done in search of a truly automatic transmission, none of it, he felt, yielding a satisfactory solution to the problem. It should be possible, he reasoned, to develop a step ratio transmission in which shifting would be accomplished using hydraulic servo-mechanisms. In 1932, having convinced Cadillac management that this approach might work, he set out to design such a device. Thompson chose four engineers to work with him, and during the next three years their designs (called, enigmatically, the "Military Transmission Project") progressed from simple two speed units to four-speed drives. These transmissions, however, were far from perfect. Thompson and his associates were particularly troubled by the "bump" of ratio change. Some means had to be found for more adequate controls in smoothing out the transition from one step gear ratio to the next before there could be any thought of commercial application.

By this time, late 1934, Cadillac management had begun to feel some misgivings about continuing financial support of automatic transmission research. But G.M. management, specifically O. E. Hunt, Engineering Vice President, was now convinced that the Military Transmission Project was of broad interest to G.M. Corporation (five years earlier Alfred P. Sloan, President of G.M., had said that it was essential to the advancement of the automobile to eliminate from the consciousness of the driver the need for shifting gears). In January 1935 the decision was made to transfer Thompson's operation from Cadillac to G.M. Central Staff under the aegis of Mr. Hunt: of the automatic transmission projects then underway in the various G.M.

divisions, both Hunt and Sloan evidently believed this one to be the most promising.

Thompson and his group worked for another year to refine their basic designs and early in 1936 began turning them over to the Oldsmobile Division for production. The unit was now a semi-automatic four speed planetary transmission requiring the conventional clutch pedal for starting and one manual shift between a two-speed low range and a two-speed high range; this shift was made under power without use of the clutch pedal. Although this transmission was marketed in 1936 as a customer option in Oldsmobiles and Buicks, Thompson perceived that a satisfactory automatic clutch had to be developed before his design could be fully realized. In June of 1936 a fifth engineer joined Thompson's group. His name was Oliver Kelly; he was transferred from G.M.C. Truck and Coach Division where he had worked since 1929 "on transmission problems including air shift synchromesh bus transmissions, hydraulic torque converter bus transmissions, *and infinitely variable friction drives.* (Italics mine) General redesign of the production semi-automatic began at this time. Incorporation of a planetary reverse gear replacing the sliding gear arrangement and the evolution of the four stage split torque fluid coupling which eliminated the clutch pedal, *combined with a new hydraulic governor and pressure modulator system for automatic control* (italics mine) produced the necessary elements for a fully automatic passenger car transmission which was given the name Hydra-Matic."[5] Nearly three years were required for this redesign, and for testing of the new device; in 1939 it was judged to be ready for production release and it appeared as an option, replacing the semi-automatic unit, on 1940 Model Year Oldsmobiles. Subsequently, as we have seen, the Hyrda-Matic became very popular indeed.[6]

The paragraph above is very important. In it one finds either suggestions of a remarkable coincidence (i.e. the appearance of Oliver Kelly and the solution of problems which had perplexed Thompson and his co-workers for several years) or evidence to support an equally surprising contention by J. O. Almen. Namely, that he, not Thompson, was responsible for the invention of the device referred to by the phrase "automatic transmission."

To find out what is behind Almen's claim we need to jump back a decade or more to a time when the automatic transmission was still a dream. Here, largely in his own words, is Almen's version of the story.

IV. J. O. Almen: Discovery of the "Missing Link"

"Forty years ago I was favored by fortune to make the greatest discovery in automobile history for the advancement of driving ease, safety and comfort for the driver and his passengers... When we speak of automatic automobile transmissions, we mean a combination of (1) a normal manual transmission, and (2) a robot that relieves the driver of all physical and mental duties in clutch engagement and disengagement and gear shifting. Unfortunately, experience has shown that few people realize that the robot is a mechanism apart from the normal transmission...I am the

5. Sperry Award for 1963, page 15.

6. Exhibit 2 shows excerpts from the 1940 Car Buyer's Guide which explains the operation of the Hydra-Matic.

inventor of the robot. Therefore, all automatic transmissions are Almen transmissions in the same sense that all airplanes are Wright Brothers Airplanes or that all telephones are Bell telephones."

J. O. Almen, 1967

J. O. Almen was born in 1886 in a sod cabin in North Dakota. He attended Washington State University, graduating in 1910 with a degree in Mechanical Engineering. The first patent issued to him was in 1913, for a calculating machine. During World War I he joined the McCook Field Aircraft Development Center of the U.S. Army, in Dayton, Ohio where he invented and developed the barrel engine for aircraft. At that time, he made the acquaintance of Charles F. Kettering, and in 1926 was engaged by Kettering to work for his research laboratory which became the G.M. Research Laboratories. By 1927 Almen had a dozen patents to his credit; by 1959 there had been 66 patents issued to him.

In April 1927 he was avanced to Head, Dynamics section of the G.M. Research Lab.[7] There, he says, he found only one project worthy of serious effort, so he began to look for new projects to expand the activities of his section. "One of my first new projects was a search for improvements of automobile transmission. Of course, this was not a new idea. Many earlier efforts had been made to find better means for ratio changes than the old clash gear boxes but none had been commercially successful. My objective paralleled the purpose of earlier workers in that all sought to change transmission ratios without disengaging the engine."

7. Material in this section taken from unpublished documents and correspondence of J. O. Almen.

Almen's terminology is very precise and sometimes unconventional; it will be helpful, therefore, to follow in some detail his description of the "automatic transmission complex."

"There has been considerable confusion, misconception and, I fear, fraudulent propaganda in circulation regarding the functions and correlation of the several components that comprise the automatic automobile transmisison complex...." There are, he explains, four components, three of which are modifications of those used in manually operated automobiles; these are 1) the transmission; 2) the main clutch; and 3) the accelerator. "The fourth part is the mechanism invented by me in 1927, that interprets the driver's will in terms of the moment. This is the 'missing link' that had defeated the creation of automatic transmissions prior to 1927." Almen's conceptual solution to the problem of gear shifting was this "missing link," the automatic control mechanism; "functionally, a device lying between engine and transmission. It has working attachments to both, but it is not an integral part of either. It relieves the driver of all physical and mental effort in clutch manipulation and gear shifting. It cannot be fully automatic because certain random driving situations arise which demand instinctive manual compensation. This requirement proved to be a very complex problem but, eventually, a simple, inimitable solution was found.... From a standing start, the necessary gear shifting from low to second to high gear is accomplished at pre-selected intervals through a speed – responsive governor. Similarly, the speed responsive governor controls the gear shifting intervals which return the transmission to low gear when stopping. The same governor also acts to

prevent engine overspeeding as would occur if the transmission is shifted to low gear while the automobile is operating at high speed.

"The actual gear shifting to or from the above selection is accomplished through suitable power units such as hydraulic servo-mechanisms.

"The above gear shifting occurs in accordance with pre-arranged schedules and it is, therefore, automatic. We come now to a very different requirement for which gear shifting cannot be automatic. I suspect that this problem was considered insuperable by many (apparently all) of the designers who, ever since the horseless carriage became a reality, spent countless hours striving for a practical means of eliminating driver difficulty associated with the need for shifting gears.

"Whether the automobile is equipped with a manual or automatic transmission, the driver must be prepared to instantly meet the inevitable emergencies that occur on the road. He must instinctively actuate the control that is provided for that purpose whether it is steering, braking, or accelerating. The latter usually requires gear shifting to second or low gear. But a person accustomed to driving an automatic transmission, which, normally, does not require means for manual gear shifting, is not prepared to instinctively react to emergency acceleration except by increasing the speed of the engine.

"To solve this problem, I connected the accelerator pedal to the gear shifting system in such a manner that depressing the accelerator pedal beyond open throttle position shifted the gear from high ratio to a lower ratio. By this device, gear shifting, to meet driving conditions which require greater drive wheel torque than is available from maximum throttle opening, requires nothing more than the natural act of depressing the accelerator."[8]

Thus Almen, having analyzed the control problem implied by an automatic transmission, was able to resolve that problem, at least in theory, by the relatively simple expedient he describes above. Although he never says so explicity, I think Almen would argue that it was his insight into the nature of the control problem, not the physical linkage between accelerator and transmission, that was significant (here is an analogy: Edison's biographer, Matthew Josephson, points out that his invention was an *idea* rather than a thing; his electric light was not merely a lamp but a system of electric lighting. Edison's achievement was not the selection of a suitable filament for incandescent lamps, it was the recognition that electric lighting would require generation and distribution of electricity at high voltage in order to subdivide it among a great many high-resistance "burners," each converting current at low amperage with great efficiency into light).

To this point Almen had worked alone; the question of which type of transmission to use did not arise until he had completed the design of the automatic device. Now, when the time came to translate this plan into a complete layout including a transmission, it became a group effort. To his top man and first assistant, Jacob Ehrlich, whom he inherited with the Dynamics

8. Exhibit 3 shows a page from one of Almen's patents on this feature.

section of the Laboratories, he added four others, all good engineers.[9]

So, in 1927, they undertook the task of developing a workable layout; the transmission, they agreed, should be of the planetary type (i.e. one with step-type gears and hydraulically operated clutches). This was an obvious choice because such transmissions had seen extensive and successful use in early automobiles—among them the Ford Model T—and had the inherent ability to shift gears while transmitting torque. The result of their efforts, Almen says, was a device almost identical to the Hydra-Matic. When this transmission had progressed sufficiently to begin final design and layout, Almen consulted with Charles Kettering, Director of the G.M. Research Labs, relative to detailing, building, and testing the unit. "Kettering suggested that I first contact the Chief Engineers of G.M.'s five manufacturing divisions....the result of this poll was 100% negative, but each suggested that Research should study the possibilities of infinitely variable types." It was decided that Almen's group should drop the planetary transmission (the year is still 1927; Thompson is working as a consultant on the Synchromesh and will not join G.M. as assistant chief engineer at Cadillac until 1929) and select the best of several infinitely variable mechanisms to be used in conjunction with the automatic control. They decided that the hard surface friction types (as used in the Carter Car Friction Drive) offered the best chance of success. "Since the good will of our potential customers, the chief engineers, was essential, and the primary purpose of our project was the development of a better automatic control system, the type of transmission was incidental."

After detailed analysis they concluded that the double toric hard surface type of transmission was capable of high efficiency, large ratio range (6.25 to 1), relatively light weight, and no serious manufacturing problems. By 1929 they had built an experimental unit and installed in in a 1930 model Cadillac. After dynamometer and road testing, the transmission was redesigned in several particulars. The most important of these were the reduction of the toric raceways from 11 inches to 8½ inches diameter and the replacement of the manual main clutch with a centrifugally actuated automatic clutch.

This improved transmission was built by the G.M. Research Laboratories. It was installed in a 1930 Buick for road tests of the new features before releasing the Automatic Transmission Research Project to Buick for production design. The Buick development program included building of more than 50 automobiles equipped with this transmission and more than 750,000 miles of proving ground and road tests (cf. Chayne's figures quoted earlier).

"As the project neared completion it was suddenly, and to me inexplicably, stopped by order of Alfred Sloan. No doubt this was on advice of a high-ranking G.M. engineer, but on what grounds was not, to my knowledge, revealed.[10] I was sorry that the

9. Two of them became general managers of GM divisions, one became Chief Engineer of Buick.

10. A friend pointed out that in *My Years with General Motors* A. P. Sloan, Jr. says of this transmission "I was convinced that it would always cost too much and I turned it down for our cars." He also says that the earlier episode of the copper cooled engine may have some bearing on this case. As related in Chapter 5 of Mr. Sloan's book, this engine had been developed by Mr. Kettering's Laboratories, the GM executive committee

Buick work was discontinued because that transmission was far superior in every respect to all other automobile transmissions, whether manual or automatic. Not only was fuel consumption reduced twenty-five per-cent, but what may be considered even more important today, smog emission would be reduced by a like amount. Stopping the Buick development retarded, but otherwise did not affect the progress of automatic transmission development by the Research Laboratories." In a letter to a G.M. official, dated May 26, 1959, Almen described the outcome of his group's continued work on the I.V. (infinitely variable) transmission.

"For maximum fuel efficiency a four cycle engine should operate near full throttle at all road speeds. Our I.V. transmission had an overall ratio range of 6.25 which meant that an "overdrive" of approximately 2.5 was available. It was, therefore, possible to closely approach the desired wide open throttle condition at any car speed above that which would stall the engine.

"The engine should never be required to operate at any speed greater than the speed of maximum horsepower. Since the useful maximum horsepower must be measured at the drive wheel tires and since the maximum tire horsepower occurs at a speed lower than the speed corresponding to maximum engine horsepower, the transmission should have sufficient ratio range to deliver maximum desired road speed with engine speed less than its speed of maximum horsepower. In fact it is not necessary to reach the peak tire horsepower because the usual power curve is quite flat as it approaches its peak.

"Before the Research I.V. transmission project was concluded we completed and extensively road tested a car in which the maximum engine speed was considerably below 2000 rpm at 95 miles per hour. The speed of maximum engine horsepower was, I believe, about 2700 rpm.

"For better accommodation of the transmission, it was located behind the rear axle. The axle gears and the transmission were in a common housing attached to the car frame. The rear wheels were mounted upon a "dead" axle and driven through universal joints. For comfort, quietness, and roadability this car has had no equal."

When work on this project was completed, Almen says, "I was content in the belief that if the question of origin of the automatic transmission should arise, history would accord to me credit for the long sought solution of that perplexing problem. I did not then, or for many years later, know that the groundwork for the theft of that credit was even then in progress."

The thieves, so far as Almen is concerned, were the members of the Sperry Board of Award. The deed was made possible by the (perhaps unwitting) co-operation of a number of General Motors employees. He proposes a "debunked" version of the Sperry Award Brochure, the essence of which is that Thompson never had any knowledge of what constituted an "automatic" transmission. The Thompson group, he says, worked at the problem without success until "finally, after four and one-half years of bungling, someone,

wanted it, but eventually it had to be rejected on the advice of division engineers led by O. E. Hunt, chief engineer of Chevrolet. Kettering wanted to resign from General Motors but was persuaded to remain. A memorandum of July 1923, quoted by Mr. Sloan, contains the words "... I believe that it is useless to attempt to establish an agreement between Mr. Kettering and Mr. Hunt ..."

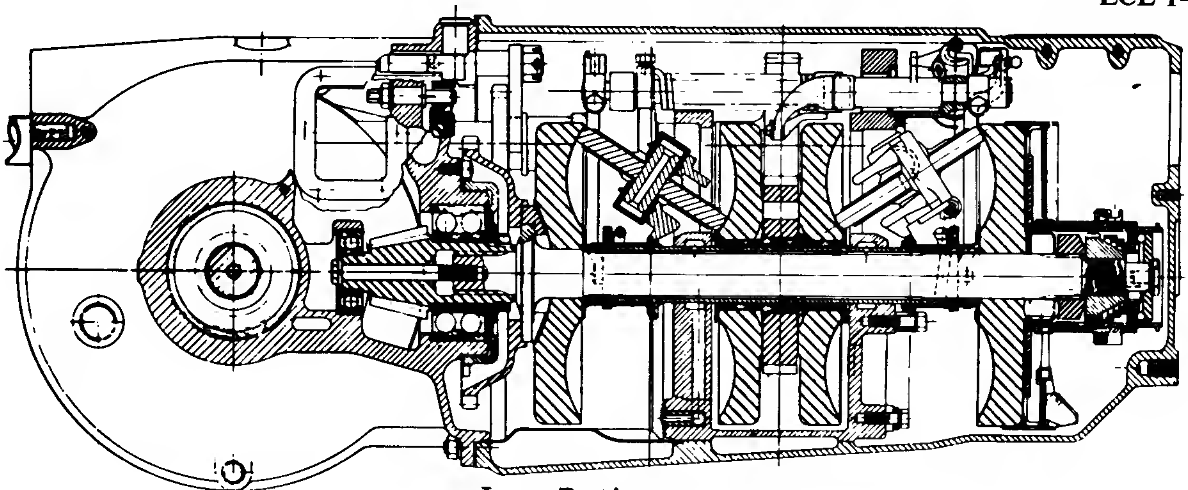
probably O. E. Hunt, went outside of Thompson's group for competent technical help in the person of Oliver Kelly. Kelly, a really good engineer, had worked with my group in G.M. research and knew what was required to make transmissions automatic." In Almen's view those lines I italicized at the end of Section III. are a "reluctant admission that Thompson, his sponsors and their entire design group, had not understood their problems. They had been fumbling in the dark. With the acquisition of a competent engineer, the addition of my automatic control system and the correction of design errors in the transmission, the long deadlocked planetary automatic transmission was soon ready for production."

V. Conclusion

The story has taken some fancy twists, we have toyed with what novelists call unreliable narration--which, it turns out, is all narration. Now, what is the point? That engineers, like the rest of us, conspire against one another? Empires built, threatened, protected at great cost, even in the boardrooms and laboratories of General Motors? Almen a victim of circumstance? The man who invented Synchromesh at age thirty-one a liar and a fool?

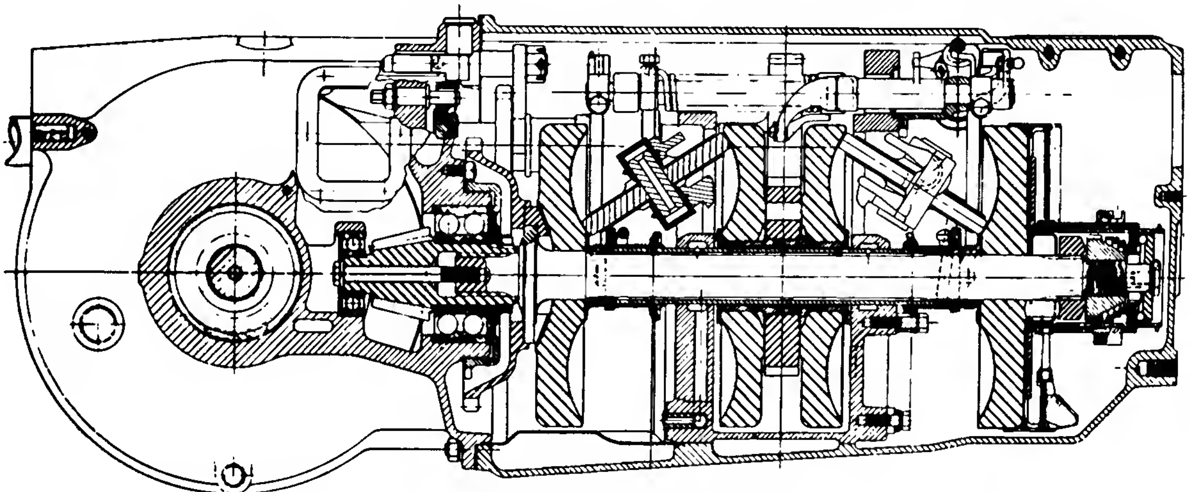
The fact is, I suspect, if the answer exists it is locked up somewhere in a vault. And I don't think it does exist. I think the story is ambiguous, and that is its attraction. Even when you deal with transmissions, infinitely variable or otherwise—so long as there are people involved, nothing will be absolutely certain.

Diagram of I.V. Transmission



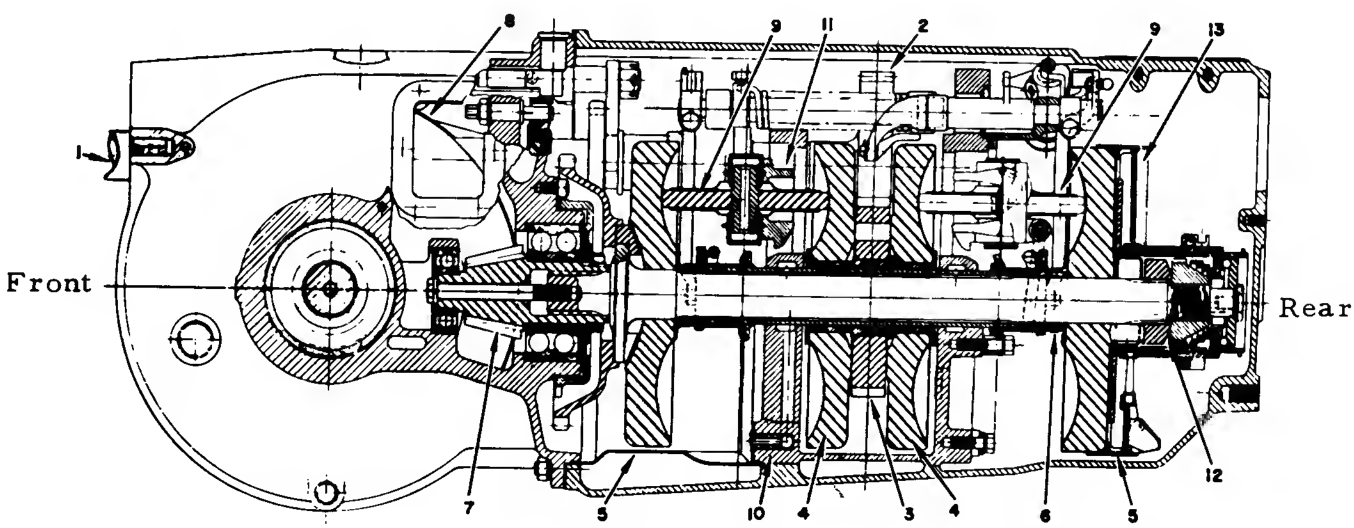
Low Ratio

Engine shaft rotates 2½ revs. while output shaft rotates one rev.



High, High Ratio

Engine shaft rotates one rev. while output shaft rotates 2½ revs.



This is High Gear in Conventional Transmissions.

Engine shaft rotates one rev. while output shaft rotates one rev.

EXHIBIT 1

LIST OF PARTS AND FUNCTIONS

2. Gear on propeller shaft driving gear 3 at engine speed.
3. Driven gear which drives the two input toric disks 4-4.
5-5 Output tores friction driven by 6 rollers 9-9.
6. Stationary structure supporting transmission shaft.
7. Rear axle bevel pinion.
8. Rear axle bevel ring gear.
9. Drive ratio change. Roller axes intersect main drive shaft when stable. To change ratio roller axes are tilted out of intersection which causes the rollers to precess until their axes are again intersecting the main shaft.
10. Supporting structure.
11. Stirrup shaped parts in which the rollers are mounted.
12. Inclined surfaces and steel balls which develop pressure between the contacting toric surfaces (4 and 5) and the surfaces of the rollers (9). Thus the pressure between the friction surfaces is always proportional to the torque being transmitted by the output shaft (7).
13. Centrifugal governor for control of transmission.

This transmission is lubricated and cooled with low viscosity oil from mid-continent wells. Reason is that the traction co-efficient is a bit greater than paraffin base oil.

HOW YOU DRIVE IT

Oldsmobile has sprung the greatest automotive sensation in many years by introducing a fully automatic four-speed transmission combined with a highly efficient liquid coupling which eliminates the conventional clutch and its pedal. All gears are the silent helical type.

The car is started from rest and driven entirely by means of the accelerator. Once the engine is running, the driver steps on the gas and away he goes. That is all there is to it. Real dyed-in-the-wool automobile fans have been talking and hoping for such a device for the past forty years, so to Oldsmobile belongs the distinction of being the first motor car maker to bring the dream true. Unquestionably this transmission is the beginning of a new trend in autmotive development.

When the accelerator pedal is depressed the liquid coupling takes hold promptly and firmly but smoothly. Unless told, no driver would suspect that the only connection between flywheel and transmission are streams of racing liquid – light, clear oil which circulates unremittingly between the driving and driven members of the coupling which do not touch.

The Hydra-Matic transmission is optional equipment on all models at only $57 extra. It is unconditionally guaranteed for one year.

In some of its basic features it resembles the semi-automatic unit brought out in May 1937. However, it has been completely redesigned to render it fully automatic. The shift control is entirely new in that it is operated hydraulically, that is, by oil pressure, whereas a number of cams, levers and rods were used in the previous device.

The transmission always starts in low gear, shifting smoothly and silently to second, third and fourth as car speed increases. Just when the shifts occur depends on throttle opening. With light throttle the car goes into fourth gear at 20 mph, whereas at full throttle the shift to fourth is made at 65 mph. This feature gives the driver ideal control over the automatic shifting process. If he wants to make a fast getaway he naturally steps hard on the accelerator pedal and secures maximum acceleration by taking full advantage of the gears.

With full throttle, shifts are made at the following car speeds: First-second, 15 mph; second-third, 30 mph; third-fourth, 65 mph. With light throttle the shifting speeds are: First-second, 7 mph; second-third, 13 mph; third-fourth, 20 mph. Opening the throttle stretches the shifting range. The greater the opening the greater the stretch. The transmission obviously performs equally well for novice or expert. In either case, the amount the throttle is opened is any driver's unconscious way of telling the car that he wants more acceleration and the transmission responds to his wish by utilizing the gears to an increasing extent as the throttle is opened. At any given throttle position the down-shifts occur at about 10 per cent lower car speed than the corresponding up-shifts.

Excerpts from CAR BUYER'S GUIDE, 1940

EXHIBIT 2

. . . . . .

It is easy to explain how both the liquid coupling and four-speed automatic transmission works. The former transmits its power from driving to driven member by the simple process of accelerating the oil in the first member and decelerating it in the second. This process will be described in a moment. The automatic transmission consists of two planetary units which provide the four forward speeds. A third planetary unit combines with the other two to give reverse. Changing from one gear to another is controlled by a centrifugal governor which is influenced by throttle position.

. . . . . .

HOW SHIFT IS MADE

The diagram illustrates the shifting mechanism in simplified form. The planetary unit is locked in direct by applying oil pressure to the six clutch pistons and at the same time the band is released by oil pressure on the band piston. Oil pressure is obtained from the main line by moving the shift valve to the left, closing the discharge port and connecting the oil pressure line to the pistons.

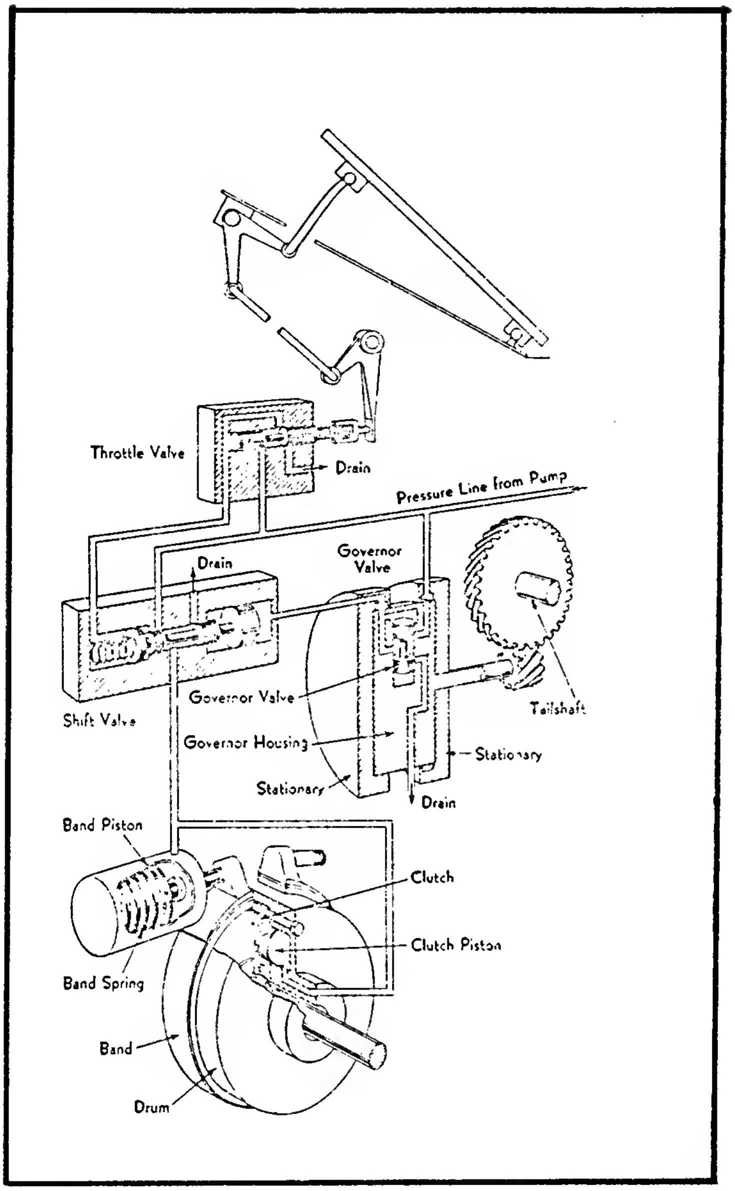
To engage the planetary gears, the shift valve is moved right shutting off the oil pressure line and opening the drain port, removing pressure from all pistons and allowing the coil spring back of the band piston to lock the band against the drum. Thus, an upshift is made by sliding the valve left and a downshift by moving it right.

The shift valve is moved by pressure on its two ends. Oil pressure on the right is controlled by the governor and is proportional to centrifugal force. On its left, in addition to spring pressure, there is also oil pressure which increases with throttle opening by means of the throttle valve connected to the accelerator pedal.

The governor consists of a piston valve sliding radially in a housing geared to the tailshaft, or rather there are two governor valves as will be explained later. The governor mechanism is so designed that the pressure on the shift valve is proportional to the centrifugal force acting on the governor – up to the shift pressure supplied by the pump. This proportioning of the oil pressure to centrifugal force is due to the fact that oil pressure acting on the top piston head of the governor valve tends to force the valve inward against centrifugal force and thus close the port through which the oil pressure is supplied. The pressure port opening grows larger in size as centrifugal force increases. Therefore the oil pressure on the shift valve increases with centrifugal force.

Consequently, the shift valve is positioned by throttle (and spring) pressure and governor pressure. When governor pressure exceeds throttle pressure an upward shift is indicated and when throttle pressure has the upper hand, the planetary gears are called into use. Thus it should be clear that upward shifts are delayed by throttle opening and accelerated by throttle closing.

The governor has two piston valves of different weight. The heavier one controls the shift from first to second; both are used for second to third, and the light one for third to fourth.



SHIFTING is jointly controlled by governor and accelerator pedal. Valves are compactly arranged in box on side of transmission.

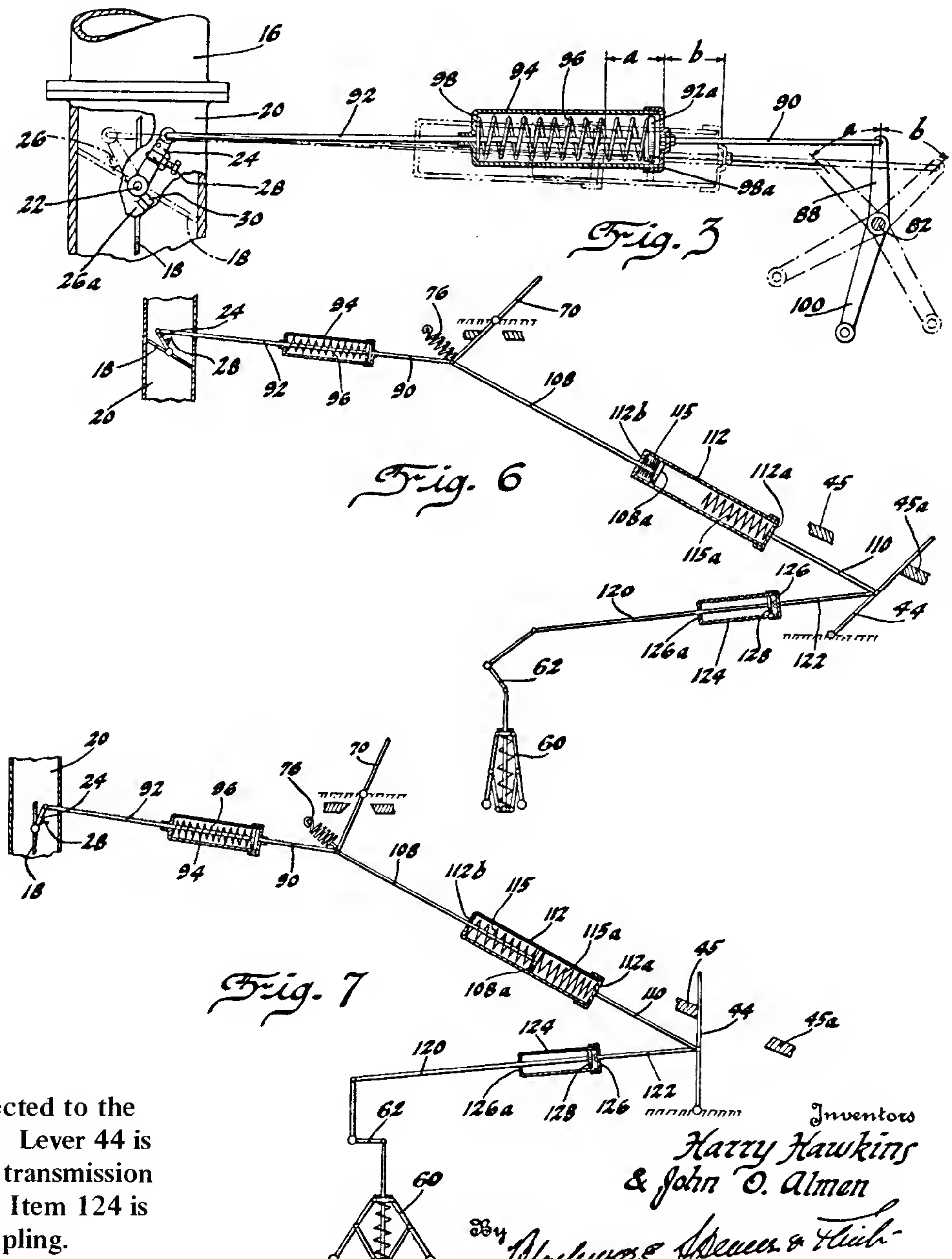
Excerpts from CAR BUYER'S GUIDE, 1940

EXHIBIT 2

Sept. 27, 1938. J. O. ALMEN ET AL 2,131,157

CONTROL FOR VARIABLE SPEED POWER TRANSMISSIONS

Filed March 9, 1931 4 Sheets-Sheet 2



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Lever 70 is connected to the accelerator pedal. Lever 44 is connected to the transmission shift mechanism. Item 124 is a lost motion coupling.

EXHIBIT 3

Excerpt from Patent 2,131,157